OPERATIONAL NEEDS FOR CUSTOM VOLUME COVERAGE PATTERNS

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1. INTRODUCTION

This report identifies some of the operational needs for custom volume coverage patterns (VCPs). Firm validation of field needs will be given when possible. Special VCPs used to meet these field needs will be broadly described in the text and specifically treated in the appendices. Future work to change VCPs will be mentioned.

The Weather Surveillance Radar, 1988-Doppler (WSR-88D) currently contains four scan strategies. Each unique volume coverage pattern (VCP) is described in the *Federal Meteorological Handbook No. 11, Part C* (1991). These volume coverage patterns are typically characterized by the number of elevation slices made by the beam and the length of time it takes the radar to complete an entire scan using those slices. For example, convective mode VCP–21 scans 9 slices in six minutes; convective mode VCP–11 scans 14 slices in 5 minutes. Ten minute scans are employed with the clear air, long pulse strategy, VCP–31, and the clear air short pulse strategy, VCP–32. These clear–air mode scanning patterns have five unique elevation angles.

The WSR–88D, using VCPs, samples return power signals to a maximum range of 460 km (248 nmi). Velocity data is collected at a maximum range of 230 km (124 nmi)(Klazura, et al,1993).

The present set of VCPs do not completely satisfy operational needs for several meteorological situations and were never designed as an all-encompassing collection. There are valid operational reasons to add new sampling strategies. New VCPs have been suggested to optimally support specific operational needs (Sirmans, 1993) and, in some cases, minor VCP parameter changes could vastly improve the sampling effectiveness at some radar sites. The overall problem to VCP customization, however, is not entirely simple and straight forward. There are machine limits and electronic constraints. Even the easy–to–change parts of VCPs must trade between data quality and data acquisition rate. Sites must also adhere to data compatibility requirements. Data sharing requirements limit VCP changes. Efforts to change are further complicated since the NEXRAD program supports three agencies with different missions. However, even under this constraint considerable flexibility in data acquisition is possible.

Changes to VCPs to optimally support the WSR–88D operators' needs vary with both site and climatology. At some WSR–88D locations, standard VCPs render the WSR-88D ineffective. For example, at some mountain sites, the 0.5° elevation slice simply overshoots significant winter weather. VCP parameter adjustments to estimate accuracy, throughput time, vertical and horizontal resolution, and signal sensitivity will provide forecasters with tools to do a better job.

2. OPERATIONAL NEEDS

The ability to vary VCP characteristics is strongly motivated by operational needs during critical weather situations. **Forecasters rely on both base data and algorithm output. In this context, operational needs of VCPs are 1) to sample specific parts of the atmosphere, 2) to increase temporal resolution, and 3) to increase spatial resolution, of the data.** It is not, however, a simple task to maximize the appropriate variables of VCPs. Each change has a tendency to take away from other desired aspects of a given VCP. A *rapid volume update* borrows from the radar's ability to *improve data sample quality* (estimate standard deviation) or *increase the sample density* (better horizontal and vertical resolution of sampled space). In other words, we may reduce data quality or resolution - to obtain a more rapid update; we may reduce the update rate - to obtain better data quality or resolution. On a positive note, there are many possible changes to VCPs which do not seriously compromise the complementary characteristics.

The investigation of operational requirements for modified VCPs led to the discovery of several significant operational problems with standard VCPs. The growing list of needs ranges from desperate field requests to solve major VCP problems to recommendations to use highly speculative hybrid VCPs to observe the atmosphere for research projects.

There are many specific operational issues which ultimately have solutions by customizing VCPs. There are special site needs due to natural terrain features. There are cultural, or man–made, beam blockage issues – such as new buildings and towers. There are places where the climatology presents special cases for the radar. The cone of silence, a non–sampled region above each radar antenna, is a greater problem for some weather offices than others since the customer population may be large beneath this un–sampled area. Volume throughput time has been identified as a problem for several reasons. Since forecasters ascertain some rapidly changing characteristics within thunderstorms to be one reason to initiate warnings, rapid volume updates are a natural outcry. Improved algorithms will help forecasts based upon temporal aspects of pattern recognition but the data flow (e.g., VCP update rate) must capture the phenomena evolution of interest.

2.1 Rapid Update VCP Needs

Faster VCP updates are generally understood to mean faster than 5 minutes. Some meteorological events, such as microburst storms, are better forecast if the radar scans more often. For example, work is underway to produce a damaging downburst algorithm for short–lived convective cells. Tornadoes are a relatively shallow atmospheric event and can spin up very quickly, especially in hurricanes. A VCP having the volume coverage of VCP-11 in 3.75 minutes is given in Appendix C.

Some have suggested the lowest elevation to be sampled half way through a volume, effectively sampling the lowest slice twice as frequently. Appealing in many ways, this VCP change would maintain present volume structures while providing a special intermediate lowest slice. Algorithm functionality should not be too difficult to predict under these conditions. It is important to note that faster antenna rotation rate does not severely degrade spectral moment estimates for most meteorological purposes since estimate standard deviation increases as the square root of antenna speed.

2.2 Vertical Resolution VCP Needs

Precipitation in hurricanes is hard to estimate because of the high shear and the shallow nature of the storm. This, and other lower atmospheric phenomenon, need to be sampled in greater detail by the radar. Denser sampling within storms can better resolve features such as mesocyclones and tornadoes while extending the range of detection.

One formal change request suggested better vertical resolution between the two lowest elevation slices. Similarly, a request (See Appendix E, Change Requests NA94–33209 and NA97–12205) was submitted by the NWS Eastern Region to insert an additional 1.0 degree elevation slice. These requests are explicitly concerned with basic weather detection limitations, especially at long ranges. Mini–super cells and precipitation estimates are of prime concern. This modification would also improve low altitude coverage at sites where terrain blockage degrades data at the 0.5˚ elevation slice.

This solution is not as simple as slightly adjusting standard elevation angles. Algorithm functionality, especially the Precipitation Processing Subsystem and Snow algorithm, are impacted if additional elevation slices are inserted into the four lowest tilts. However, the ability to increase the range of severe weather and flood detection and improve warnings validates vertical resolution improvements.

Since greater vertical resolution and better low altitude coverage would require more time for a pattern to complete, a favorable compromise could be to collect data as fast as possible at intermediate and upper elevation slices. There are many who believe 0.5° increments in the lower elevation slices will provide better precipitation estimates, reduce algorithm interpolation, and increase range effectiveness of the radar.

A VCP with the same volume coverage and throughput time as VCP-11 but with increased elevation resolution is given in Appendix D.

2.3 Horizontal Resolution VCP Needs

There are several WSR-88D sites around the country where atmospheric phenomenon are climatologically finer in width than other locations (e.g., U.S. Southwest desert dry microbursts, Eastern U.S. mini-super cells). Many radar researchers believe azimuthal increments of 1.0° are too coarse, especially as target distance from the radar is increased. Better horizontal data resolution can improve mean rotational velocity estimates and better define core diameters of mesocyclones (Wood and Brown, 1998) and tornadoes (Brown and Wood, 1998). As more horizontal resolution studies proceed, VCPs should be devised based upon research findings, especially as warning capabilities are obviously improved.

2.4 Multiple PRF VCP Needs

There is a need to reduce the amount of range folding and velocity dealiasing errors on product displays. OSF and NSSL studies (Conway et al, 1998) have been underway for several years to find solutions to these problems using Multiple Pulse Repetition Frequency techniques. Experimental VCPs have been used to successfully demonstrate Multi-PRF techniques. In order for promising Multi–PRF techniques to support warning operations, new VCPs must be implemented.

2.5 Examples of Geographical-Climatological VCP Needs

Mountain Site VCP Needs.
Many mountain–sited WSR–88D RDAs (Radar Data Acquisition) overshoot the boundary layer and completely miss detection of significant weather events. Numerous appeals, especially from Western Region personnel, and formal requests (See Appendix E, Change Request WRH190N) to lower the lowest elevation slice have been sent to the OSF. Intuitively, modifying VCPs for mountain sites will reduce the serious limitations presently imposed. However, the success of lowering the antenna elevation below 0.5° to observe valley weather offers somewhat unknown results and will require experimentation. Each mountain site with beam–overshooting difficulties is somewhat unique; lowering the beam at some mountain locations will only increase blockage of the radar beam.

Prototype VCPs with lower scan angles such as suggested by Sirmans, 1994, will be required in order to demonstrate the benefits and capabilities (the mountain site problem is discussed in Appendix A). The NWS Western Region has offered to evaluate the usefulness of lower scan angles using the Salt Lake City RDA.

Lake Effect Snow VCP Needs.

Over twenty WSR-88D sites around the Great Lakes region have customer support difficulties during Lake Effect Snow (LES) events (LES project, NWSFO Buffalo final report, 1997). Customer satisfaction diminishes considerably with range from the radar at Great Lake sites during Lake Effect Snow events. Steps need to be taken to improve public warning and forecast services for many heavily populated areas where radar coverage is limited. A solution is to apply custom volume coverage patterns. An OSF engineering study (Sirmans and Steadham, 1998) has examined several LES sites and established parameters for candidate LES VCPs. Conjuring workable VCPs for specific needs seems to be a relatively simple task. VCP implementation will, of course, require electro–magnetic field analysis and legal agreements and letters of confidence with airport authorities and other involved parties.

National Weather Service leaders have announced weather services related to Lake Effect Snow events must be improved. To better detect Lake Effect Snow events, different types of remotely sensed data may eventually be merged to offer offices the needed observing tools. In the meantime, custom VCPs have already been designed, but not tested, to enable affected radar sites the capability to detect these shallow wintertime events near large bodies of water. Adjusting beam geometry seems a small price compared to the alternative solution to add a new radar site.

Forecasters tasked against these shallow winter snowstorms say algorithm output is far less important than the ability to remotely sense and geographically position snow bands (Mahoney interview, 1998). If algorithms are adversely affected for an indefinite time as changes are made to VCPs, operational impacts should be judiciously weighted. This would provide NWS offices a much greater opportunity to effectively serve presently dissatisfied customers.

Snow accumulation algorithms presently offer an incomplete solution since the beam often simply overshoots the weather. Reasonably, if the average inversion height of Lake Effect Snow event is 6,500 feet AGL, by lowering the lowest beam slice to 0.3 degrees (Smith, 1997), an increase of 34% in effective areal coverage is realized. Optimum detection of Lake Effect Snowstorms will require a VCP starting with the minimum practical elevation angle and smaller elevation angle increments. Two VCPs of this genre are given in Appendix B.

2.6 Other VCP Needs

There have been a large variety of proposed VCPs. Many are based upon site–specific difficulties related to siting constraints. Some are based upon climatological regions, for instance, coastal sites where special Marine Layer VCPs are needed. Different meteorological events occurring at different ranges imply a need for specialized radar scans.

There is a general need to monitor middle levels of the atmosphere for convective initiation. Somewhat related, the FAA wants constant altitude layered products. In order to effectively satisfy this need, sufficient vertical spatial resolution must be available at middle levels. The VCP given in Appendix D will probably address this need.

Shadow mitigation may be optimized through carefully devised, site–specific VCP designs. Terrain–propagation algorithms can be developed to establish precise site terrain blockage and theoretical clutter return, as suggested by Sirmans, 1993. Reductions in the Cone of Silence area may be more pressing for some sites than others due to customer proximity concerns. Full vector Doppler wind measurements could require minor adjustments to VCPs. Central collection schemes will tend toward greater data compatibility. The National Centers for Environmental Prediction (NCEP) report ambitious future requirements for radar data into the next decade.

3. SUMMARY

Valuable custom VCPs could be implemented with little expense. More costly paths exist to solve some VCP field needs. Ultimately, better service to customers and more complete utilization of the WSR–88D capabilities could be realized with these changes. Considering the cost to install a new radar, custom VCP solutions, whenever possible, look attractive as a means to solve field requirements. Efforts to build and deploy custom VCPs should always be validated by field requirements. The OSF must specifically define new patterns, make prototypes, and test. This is not a new vision. It is no accident the legacy NEXRAD system has provisions for twenty-one VCPs at the RPG and an additional twenty-one VCPs at the RDA.

There are many impacts to consider; VCP changes will require full-thread system considerations. There are radar measurement uncertainties (Howard et al, 1997) and algorithm performance matters. New VCPs should be appraised by potentials for new and improved algorithms, reduced or improved sample estimates, longer or shorter acquisition times, narrowband and CPU loadshedding, data compatibility, other system requirements, and predictable operational difficulties. Actions to implement custom VCPs will substantially support most technical needs established by the NEXRAD Technical Advisory Committee. Conspicuously notable is TN–1, (Data Acquisition Rate Needs and Strategies).

By lowering the lowest slice to 0.3° (P. Smith, 1997) at flat locations and by sampling with greater vertical resolution (e.g., elevation slices increasing by 0.5°), many feel precipitation estimates and algorithm performances can only improve. Prototype VCPs can easily be designed to incorporate theoretical advantages to radar sensing of precipitation events. Again, experimentation may be the only confident way to be certain of improvement.

4. REFERENCES

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APPENDIX A
Mountain Top Volume Coverage Pattern Needs

There are locations where the WSR–88D RDA is located on mountainous terrain. Some sites are even overlooked as mountain sites. Large metropolitan centers, such as Los Angeles, have altitudes near sea–level and, yet, are often served by radars located in higher terrain. Thus, VCP problems associated with mountain sites are frequent.

The OSF wants to incorporate a suite of custom Volume Coverage Patterns (VCPs) based upon operational needs. One of the most important of these field needs for customized VCPs is to accommodate for radar sites in mountains and hills. There are often site–specific problems in beam blockage and overshooting at these mountain top sites. Nationwide, the western United States has the vast majority of these mountain top–related problems (See Table A–1, from Western Region Headquarters).

ID	WFO	RDA	Elevation ft MSL Ht of nearby population/terrain	Delta
KICX	Cedar City, UT	10600	valleys and canyons 5000–6000	5600
KGJX	Grand Junction, CO	10200	Grand Junction and valleys < 5000	5200
KGRX	Reno, NV	8300	Reno 4500 @ 30 miles	3800
KMSX	Missoula, MT	7855	Missoula 3240 @ 20 miles	4615
KMAX	Medford, OR	7513	Medford 1400 @ 30 miles	6113
KSFX	Flagstaff, AZ	7417	Flagstaff 7000 ft; valleys <5000	417
KLRX	Elko, NV	6744	Elko & valleys < 5000	1744
KSOX	San Diego, CA	3024	Salt Lake City 4210 @ 40 miles	2360
KMTX	Salt Lake City, UT	6570	Tucson 2600 @ 25 miles	2602
KEMX	Tucson, AZ	5202	Near sea level	3469
KMUX	Monterey, CA	3469	Near sea level	3024
KVTX	Los Angeles, CA	2726	Near sea level	2726
KBHX	Eureka, CA	2402	Near sea level	2402

*note: Actual Delta heights using the 0.5 deg beam center are range dependent

Table A-1 Western U.S. WSR–88D RDA heights versus underlying terrain/population areas.

These special sites, and others, are unable to detect frequently occurring, low-level phenomenon below the one–half degree slice. Presently, forecasters find other ways to solve the problem, whenever possible. A description of problems with one mountain top site will serve to illustrate.

The forecasters at the Los Angeles NWS Forecast Office must use several radars to support their County Warning Area (CWA). This data sharing dependancy, which possesses added complexities, includes the use of DoD radars at Vandenberg AFB (KVBG) and Edwards AFB (KEDW). Sometimes the Monterey radar (KMUX) is used for storms approaching from the northwest. However, forecasters must depend primarily on two radars, one at Sulphur Mountain (KVTX) and one in the Santa Ana Mountains (KSOX) for support to the Los Angeles metropolitan area including Ventura County. Both these radars are on ridge lines at about 3000 feet above sea level. Consequently, a lot of weather, especially stratiform rain, sneaks in beneath the lowest VCP elevation slice. One event in December 1994 produced three inches of rain that was completely undetected by radar 30 to 40 miles from the radar! Radar also missed detection of nearly 30 waterspouts during the 1997–98 winter season that moved onshore to spawn F0 or F1 tornadoes.

As illustrated at the Los Angeles Forecast Office due to mountainous terrain, during convective events when one may expect echoes tall enough for the radar to usefully detect, beam blockage is an issue. Convective precipitation estimates using the KVTX radar are usually pretty good except for severe beam blockage to a 6000 foot ridge line to the north. Precipitation estimates from storms beyond this blockage are almost totally lost since the lowest four elevation angles are unusable.

For stratiform events, which has included recent, spectacular flooding events in Southern California, rain cloud tops are seldom above 20,000 ft and are often below 15,000 ft (sometimes less than 10,000 ft). The vast majority of people live in these “valleys” of Southern California. About 7.6 million NWS customers must be served using the KVTX and KSOX radars. However, in a recent study (requested by GAO), the KVTX radar only captured about 42 percent of the rain measured in selected gages during major stratiform events. The KSOX radar captured a bit less (David Danielson email interview).

It should be noted that all elevated radar sites do not have the same problems. For instance, the Edwards AFB radar sits at 2757 ft, but the surrounding basin averages about 2500 ft.

Given current VCPs, those radars on top of mountains overlooking large cities will continue to overshoot low level weather phenomena that can be hazardous. These radars can not identify low level shears of tornadoes and microbursts. They can not detect boundaries where windshifts occur and thunderstorms can initiate; and they can not accurately estimate precipitation, especially in winter. Custom VCPs can be devised using elevation scans at lower, perhaps even negative elevation angles, allowing mountain top radars a way to effectively scan important low level weather phenomena. Pathways to authorize and test the effectiveness of custom VCPs for mountain sites should proceed soon, for the delay in effective radar usage is extremely costly as proven by past events.

The following table shows the height of the center of the radar beam at various ranges. From mountain top sites, one must add the drop–off in terrain to estimate the height above ground. If the top of a stratiform weather target is 15,000 feet MSL, or less, it is no wonder mountain sites struggle with radar data.

	25.0	37.5	50.0	62.5	75.0	87.5	100.0	112.5	125.0	**nmi**
	46.3	69.5	92.6	115.8	138.9	162.1	185.2	208.4	231.5	**km**
elevation (degree)										
0.00	456	1026	1825	2851	4106	5588	7299	9238	11405	**feet**
0.05	589	1225	2090	3183	4503	6052	7829	9834	12068	
0.10	721	1424	2355	3514	4901	6516	8360	10431	12730	
0.15	854	1623	2620	3845	5299	6980	8890	11027	13393	
0.20	986	1822	2885	4177	5697	7444	9420	11624	14056	
0.25	111	2021	3150	4508	6094	7908	9950	12221	14719	
0.30	125	2220	3416	4840	6492	8372	10481	12817	15382	
0.35	138	2418	3681	5171	6890	8836	11011	13414	16045	
0.40	151	2617	3946	5502	7287	9300	11541	14010	16707	
0.45	164	2816	4211	5834	7685	9764	12071	14607	17370	
0.50	178	3015	4476	6165	8083	10228	12602	15203	18033	
0.55	191	3214	4741	6497	8480	10692	13132	15800	18696	
0.60	204	3413	5006	6828	8878	11156	13662	16396	19359	
0.65	218	3611	5271	7160	9276	11620	14192	16993	20021	
0.70	231	3810	5537	7491	9673	12084	14723	17589	20684	
0.75	244	4009	5802	7822	10071	12548	15253	18186	21347	
0.80	257	4208	6067	8154	10469	13012	15783	18782	22010	
0.85	271	4407	6332	8485	10866	13476	16313	19379	22672	
0.90	284	4606	6597	8816	11264	13940	16843	19975	23335	
0.95	297	4804	6862	9148	11662	14404	17374	20572	23998	
1.00	310	5003	7127	9479	12059	14868	17904	21168	24661	
1.05	324	5202	7392	9811	12457	15331	18434	21765	25323	
1.10	337	5401	7657	10142	12855	15795	18964	22361	25986	

Table A-2 WSR–88D Beam Height at Various Ranges from 0° – 1.1° Elevation Angles

APPENDIX B
Volume Coverage Pattern for Dense Sampling of Lower Atmosphere

Tables B-1 and B-2 give two preliminary VCPs configured for dense sampling of the lower atmosphere. Both cover a volume bounded by 0.3^{N} and 6.3^{N} providing a minimum altitude coverage of 10,000 feet at ranges greater than 15 nautical miles. Also, both use 0.5^{N} elevation increments up to 2.3^{N} and 1.0^{N} increments from 2.3^{N} to 6.3^{N}. This pattern provides dense coverage at altitudes below 10,000 feet. The operational differences between VCP B-1 and VCP B-2 are throughput time and radar sensitivity.

TABLE B-1
PRELIMINARY VOLUME COVERAGE PATTERN: VCP B-1
9 unique elevations in 10 minutes

Scan Strategy - Dense sampling of lower atmosphere - Long Pulse (radar sensitivity of -15dBZ at 50 km)								
Scan							SD at W = 2ms^{-1} SNR > 10dB	
Sweep	Elevation (deg)	Waveform Type	Rate (rpm)	Period (sec)	Total minutes	PRF #	SD[Z] dB	SD[V] ms^{-1}
1	0.3	CS	1.0	60	1.0	1	.8	
2	0.3	CD	2.0	30	1.5	2		.4
3	0.8	CD	1.0	60	2.5	2	.8	.3
4	1.3	CD	1.0	60	3.5	2	.8	.3
5	1.8	CD	1.0	60	4.5	2	.8	.3
6	2.3	CD	1.0	60	5.5	2	.8	.3
7	3.3	CD	1.0	60	6.5	2	.8	.3
8	4.3	CD	1.0	60	7.5	2	.8	.3
9	5.3	CD	1.0	60	8.5	2	.8	.3
10	6.3	CD	1.0	60	9.5	2	.8	.3

600 seconds throughput = 570 seconds scan + 30 seconds overhead

VCP B-1 uses long pulse and delivers a detection sensitivity of -15.5 dBZ at 50 kilometers with a throughput time of 10 minutes (same as VCP-31 and 32). This would be the VCP of choice for dense, low altitude sampling in situations where sensitivity is important and temporal change is slow as in clear air monitoring, stratiform rain, and lake effect snow events.

VCP B-2 uses short pulse and delivers a detection sensitivity of -7.5 dBZ at 50 kilometers. This would be the VCP of choice for dense, low altitude sampling in meteorological situations where temporal sampling is important and sensitivity is secondary. Low altitude or distant convective events could be well monitored using this coverage pattern. Detection is also adequate for stratiform rain and lake effect snows.

TABLE B-2
PRELIMINARY VOLUME COVERAGE PATTERN: VCP B-2
9 unique elevations in 5 minutes

Scan Strategy - Dense sampling of lower atmosphere - Short Pulse (radar sensitivity of -7.5 dBZ at 50 km)								
Scan							SD at W = 2ms^{-1} SNR > 10dB	
Sweep	Elevation (deg)	Waveform Type	Rate (rpm)	Period (sec)	Total minutes	PRF #	SD[Z] dB	SD[V] ms^{-1}
1	0.3	CS	2.40	25	0.42	1	0.65	
2	0.3	CD	2.79	21.5	0.78	5-8		0.48
3	0.8	CS	2.40	25	1.19	1	0.65	
4	0.8	CD	2.79	21.5	1.55	5-8		0.48
5	1.3	B	2.17	27.7	2.01	3	0.68	0.50
6	1.8	B	2.17	27.7	2.47	3	0.68	0.50
7	2.3	B	2.17	27.7	2.94	3	0.68	0.50
8	3.3	B	2.17	27.7	3.40	3	0.68	0.50
9	4.3	CD	2.79	21.5	3.76	5-8	0.68	0.48
10	5.3	CD	2.79	21.5	4.11	5-8	0.68	0.48
11	6.3	CD	2.79	21.5	4.47	5-8	0.68	0.48

300 seconds throughput = 268.3 seconds scan + 31.7 seconds overhead

Concerning Lake Effect Snow

In email correspondence, Ed Mahoney wrote: “Lake Effect snow is the number one forecasting problem for the 20 or so NWS sites around the Great Lakes from November to March. Typical lake effect storms (defined as greater than 6 inches of snow at one location over only 12 hours) occurred about 14 times (each storm got its own name!) during the 1996-1997 LES season.”

The email continued:

> Some of these storms lasted over 48 hours in the same county. One LES storm, in Montague NY, dumped over 90 inches of snow within 36 hours. With respect to population, the Great Lakes region has one of the highest population densities within the U.S. Within our area of responsibility, the Buffalo (1.3 million metropolitan area) and Rochester (3/4 million metro region) area routinely crippled.
>
> These are not synoptic-scale storms. Lake effect snow storms extend only through the boundary layer and are capped by the subsidence inversion following a cold-frontal passage. LES storms that generate warning criteria snowfalls typically extend only up to 7,000 ft off of Lake Erie and 8,500 ft off of Lake Ontario. Radar is our number one tool at detecting LES storms...yet this tool was sited using summer-convective criteria using summer-convection VCPs.
>
> Our office used the WSR-57 very effectively using a lowest elevation cut at 0.2 degrees. With the WSR-88D, the lowest beam becomes partially filled (assuming a .95 degree beamwidth) at only 54nm from the radar. This yields about half of our area where the reflectivity values of the Lake Effect Snow storms are underestimated because of the beam overshooting the tops. (Rochester gets hammered on a regular basis during with little detection capability). Poor coverage impacts about 40% of our population primarily near Rochester and the two counties to its east.
>
> To see that we have a problem with siting radars for Lake Effect Snow just look at the "unplanned" radar that had to be installed in North Webster IN.

Exhibit B–1 Email from Edward Mahoney, SOO at Buffalo, NY

In determining the minimum practical elevation angle at Lake Effect Snow sites, the radar horizons at five sites were examined in detail. Results are tabulated below. It appears the lowest elevation angle with acceptable blockage is about 0.3^{N}.

	SECTOR	OCCULTATION ϕ=0.3°	CULTURAL ϕ=0.3°
KTYX - Fort Drum, NY	**200° - 050°**	**< 10%**	
KLOT - Chicago, IL	**355° - 110°**	**< 30%**	**< 30%**
KBUF - Buffalo, NY	**200° - 090°**	**< 30%**	**< 30%**
KCLE - Cleveland, OH	**240° - 090°**	**< 30%**	**< 30%**
KMQT- Marquette, MI	**280° - 120°**	**< 45%, > 60%, 325°- 337°**	*****

*** 1°elevation blocked from 20-32°, 305-347°**

APPENDIX C
Rapid Update Volume Coverage Pattern

Operationally, the volume coverage and elevation resolution of VCP-11 has proven to be satisfactory for most convective weather situations. However, the five minute throughput time has proven to be marginal for short-lived meteorological events. Table C-1 is a rapid update version of VCP-11 with a throughput time of 3.75 minutes.

This VCP should adapt to such events as rapid moving storms, tornadoes, and wet and dry microburst events.

TABLE C-1
PRELIMINARY VOLUME COVERAGE PATTERN: VCP C-1
14 unique elevations in 3 minutes 45 seconds

Scan Strategy - Rapid Update VCP Minimum throughput time for VCP-11 coverage - Short Pulse (radar sensitivity of -7.5 dBZ at 50 km)								
Scan							**SD at W = 4ms^{-1} SNR > 10dB**	
Sweep	**Elevation (deg)**	**Waveform Type**	**Rate (rpm)**	**Period (sec)**	**Total minutes**	**PRF #**	**SD[Z] dB**	**SD[V] ms^{-1}**
1	**0.5**	**CS**	**3.5**	**17.1**	**0.29**	**1**	**.55**	
2	**0.5**	**CD**	**4.0**	**15.0**	**0.54**			**.89**
3	**1.45**	**B**	**4.5**	**13.3**	**0.76**	**1**	**.67**	**.95**
4	**2.4**	**B**	**4.5**	**13.3**	**0.98**	**2**	**.67**	**.95**
5	**3.35**	**B**	**4.5**	**13.3**	**1.2**	**3**	**.67**	**.95**
6	**4.3**	**B**	**4.5**	**13.3**	**1.4**	**3**	**.67**	**.95**
7	**5.25**	**B**	**4.5**	**13.3**	**1.6**	**3**	**.67**	**.95**
8	**6.2**	**B**	**4.5**	**13.3**	**1.9**	**3**	**.67**	**.95**
9	**7.5**	**CD**	**4.8**	**12.5**	**2.1**		**.65**	**.91**
10	**8.7**	**CD**	**4.8**	**12.5**	**2.3**		**.65**	**.91**
11	**10.0**	**CD**	**4.8**	**12.5**	**2.5**		**.65**	**.91**
12	**12.0**	**CD**	**4.8**	**12.5**	**2.7**		**.65**	**.91**
13	**14.0**	**CD**	**4.8**	**12.5**	**2.9**		**.65**	**.91**
14	**16.7**	**CD**	**4.8**	**12.5**	**3.1**		**.65**	**.91**
15	**19.5**	**CD**	**4.8**	**12.5**	**3.3**		**.65**	**.91**

225 seconds throughput = 199.64 seconds scan + 25.36 seconds overhead
batch α 0.17

APPENDIX D
Dense Sampling Volume Coverage Pattern with VCP-11 Throughput

A recurring operational need is smaller elevation increments, especially at the low and intermediate elevations. Table D-1 (next page) gives a coverage pattern having the same throughput rate as VCP-11 with four additional unique elevation slices. This preliminary VCP has 0.5^{N} elevation increments up to 3.35^{N}. VCP D-1 contains 18 unique elevation slices and throughput in five minutes.

This VCP should adapt to shallow convection with embedded cells such as hurricanes and mini-super cells. It will also improve coverage of sites having beam blockage at the low elevation angles by reducing the gaps between beams while capturing the minimum unobstructed beam.

TABLE D-1
PRELIMINARY VOLUME COVERAGE PATTERN: VCP D-1
18 unique elevations in 5 minutes

Scan Strategy - Dense Sampling VCP Dense Low Elevation Sampling with VCP-11 coverage - Short Pulse (radar sensitivity of -7.5 dBZ at 50 km)								
Scan							SD at W = 4ms^{-1} SNR > 10dB	
Sweep	Elevation (deg)	Waveform Type	Rate (rpm)	Period (sec)	Total minutes	PRF #	SD[Z] dB	SD[V] ms^{-1}
1	0.5	CS	3.5	17.1	0.29	1	.55	
2	0.5	CD	4.0	15.0	0.54			.89
3	1.0	CS	3.5	17.1	0.82	1	.55	
4	1.0	CD	4.0	15.0	1.1			.89
5	1.45	B	4.5	13.3	1.3	1	.67	.95
6	1.92	B	4.5	13.3	1.5	2	.67	.95
7	2.4	B	4.5	13.3	1.7	2	.67	.95
8	2.85	B	4.5	13.3	2.0	2	.67	.95
9	3.35	B	4.5	13.3	2.2	3	.67	.95
10	4.3	B	4.5	13.3	2.4	3	.67	.95
11	5.25	B	4.5	13.3	2.6	3	.67	.95
12	6.2	B	4.5	13.3	2.8	3	.67	.95
13	7.2	CD	4.8	12.5	3.1		.65	.91
14	8.4	CD	4.8	12.5	3.3		.65	.91
15	9.6	CD	4.8	12.5	3.5		.65	.91
16	10.8	CD	4.8	12.5	3.7		.65	.91
17	12.0	CD	4.8	12.5	3.9		.65	.91
18	14.0	CD	4.8	12.5	4.1		.65	.91
19	16.7	CD	4.8	12.5	4.3		.65	.91
20	19.5	CD	4.8	12.5	4.5		.65	.91

300 seconds throughput = 270.92 seconds scan + 29.08 seconds overhead
batch α 0.17

APPENDIX E
Some Requests for Custom VCPs

Change Request NA94–33209
ADD INTER LOW LEVEL ELEV CUT TO THE VCP

Description:

The vertical spacing between the first and second elevation cuts is currently 0.95 degrees in all VCPs. This difference creates a significant height discrepancy in the Precipitation Processing System (PPS) hybrid scan (about 3000 feet at 26 nautical miles) which frequently results in rings of strong discontinuity in precipitation estimation, particularly when near the “bright band” or in regions of tropical rainfall

Proposed Solution:

Add an intermediate cut between the first two cuts. This cut should be slightly less than half way between the current first and second cuts so to minimize the vertical discrepancies in the hybrid scans. For the standard VCPs, a 0.9 degree cut should be added between the 0.5 and 1.45 degree cuts.

Change Request NA97–12205
Title: VOLUME COVERAGE PATTERNS WITH A 1.0 DEGREE ELEVATION SLICE

Description:

Eastern Region requires the addition of new Volume Coverage Patterns (VCPs) for the precipitation mode of the WSR-88D. The new VCPs should resemble existing VCPs 11 and 21 with the addition of a 1.0 degree elevation slice for both the Contiguous Doppler (CD) and Contiguous Surveillance (CS) slices. To keep the VCPs with a five to six minute update rate, several of the highest elevation slices of existing VCPs 11 and 21 may have to be eliminated. The OSF should determine this after testing.

Proposed Solution:

These additional VCPs allow the basic weather detection capabilities of the WSR-88Ds to be enhanced, especially at long ranges. Additionally, sites with significant siting deficiencies (like NWSO GSP) will recognize drastic improvement in algorithm operations for those areas hampered with significant terrain blockage problems on the 0.5 degree elevation slice.

The additional VCPs and the resulting improvement to low-altitude radar coverage will help NWSO GSP and other NWS offices in their efforts to provide timely and accurate warning decisions for the public within their CWAs and HSAs. The impact, in general, will be positive. The OSF will need to provide training to field offices on the use of these new VCPs. It is anticipated that detection of low-altitude severe weather and operations of the precipitation algorithms will be improved using this VCP. These VCPs may create a slightly larger "cone of silence" near the radar during precipitation mode and the performance of some volume products like VIL and ET may not be as efficient near the radar site. Therefore, as is currently done today, each Unit Radar Committee will need to decide which VCP will best meet the operational needs of the Tri-Agency users.

Change Request WRH190N
Title: NWSFO SALT LAKE CITY LOWER SCAN ANGLES

Description:

The NWSFO Salt Lake City, in cooperation with the National Severe Storms Laboratory and the Operational Support Facility, request permission to lower the Salt Lake City antenna below 0.5 degrees. (At this time, the antenna can be lowered to 0.2 degrees with no technical problems anticipated.) The Salt Lake City RDA, like many other radar sites in the WEST, is a mountaintop location; hence, the lowest elevation scan is well above the boundary layer. Boundary layer data is important for forecasting and tracking: thunderstorm development, outflow boundaries, low level precipitation events, mountain/valley drainage winds, and many other phenomena. Lowering the scan angle will permit better observations on this crucial portion of the atmosphere.

Benefits:

The primary benefits of this change are to operationally determine the problems and advantages of lowering the antenna at mountaintop sites. Results from lowering the Salt Lake City scan angle will be proposed as formal changes to other WSR-88D when appropriate.

The Salt Lake City NWSFO is presently involved in a Proof of Concept project. This project maintains a real-time level II ingest and display system using NSSL software. Therefore, the means to quantify the benefits of this change are already operating.